Fatigue Crack Growth in Peened Friction Stir Welds

Scott Forth and Omar Hatamleh
National Aeronautics and Space Administration
Johnson Space Center, Houston, Texas

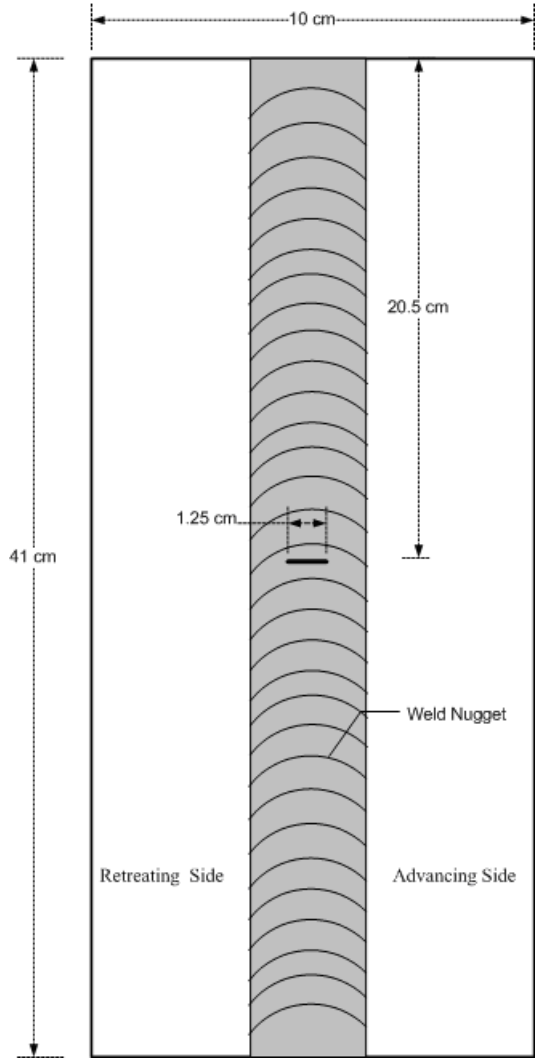
Overview

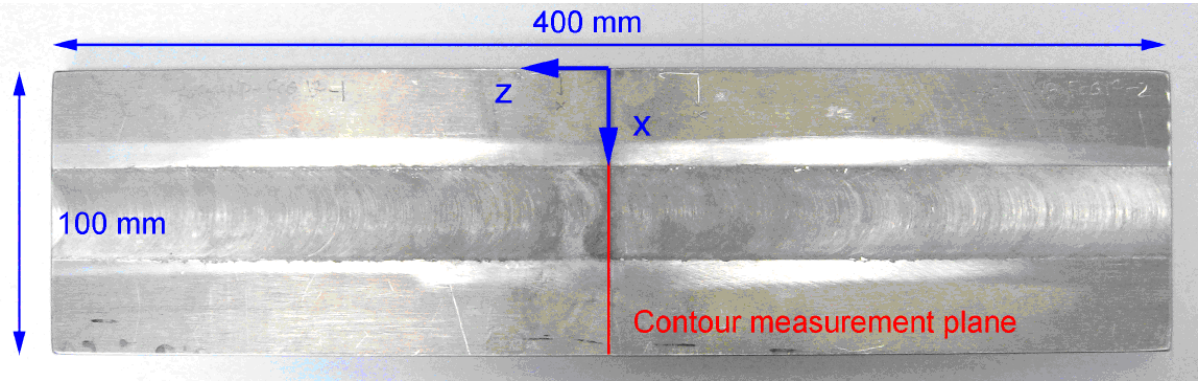
- Aluminum alloys and testing conditions
- Friction stir welding aluminum
- Laser and shot peening
- Fatigue crack growth testing
- Observations

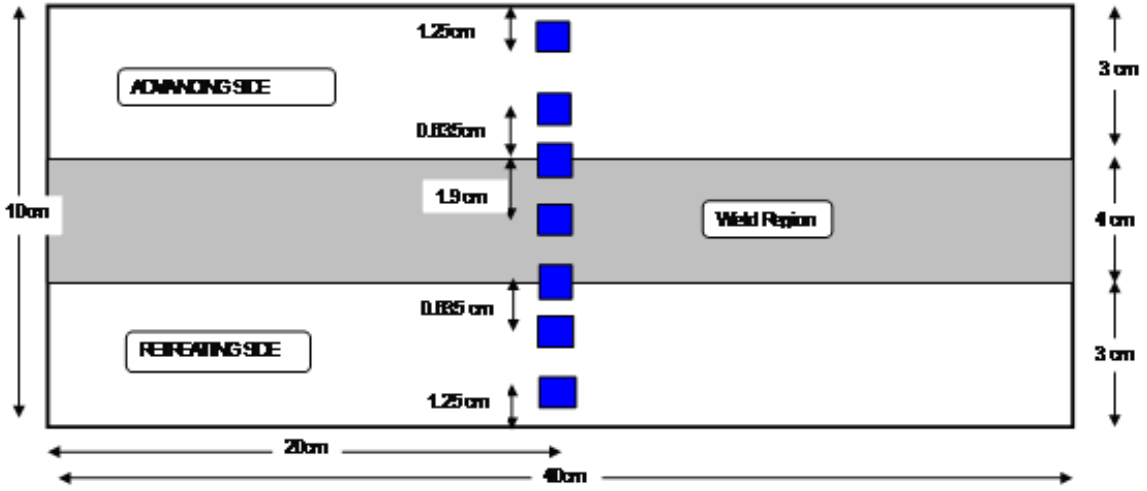
Aluminum alloys

- **7075-T73 aluminum**
  - Common alloy used in planes, trains, and automobiles
- **2195-T8**
  - Common alloy in space applications (External Tank)
- **Welding and Peening**
  - Two plates 90 x 15 x 1.25 cm
  - Butt-weld, single pass, tool speed 300 RPM CCW, 15 cm/min
  - Tool shoulder dia. 3.3 cm, probe dia. 0.92 cm
  - Glass shot peening 0.008-0.012A, 200% coverage
  - Laser peening rastered, 3% overlap, 5 GW/cm^2 for 18 ns, 3 layers offset 33%

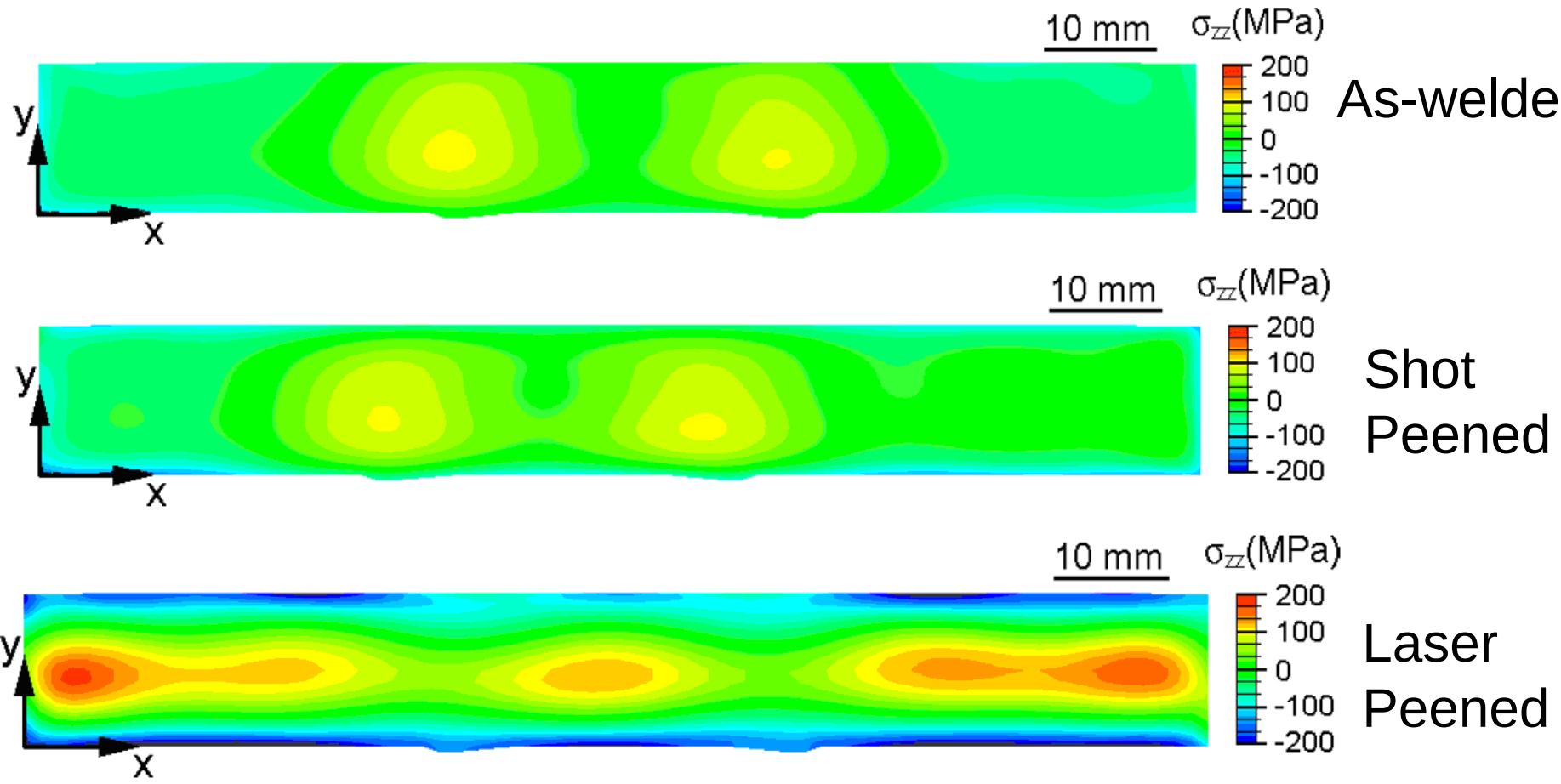
Specimen Design and Measurement Locations





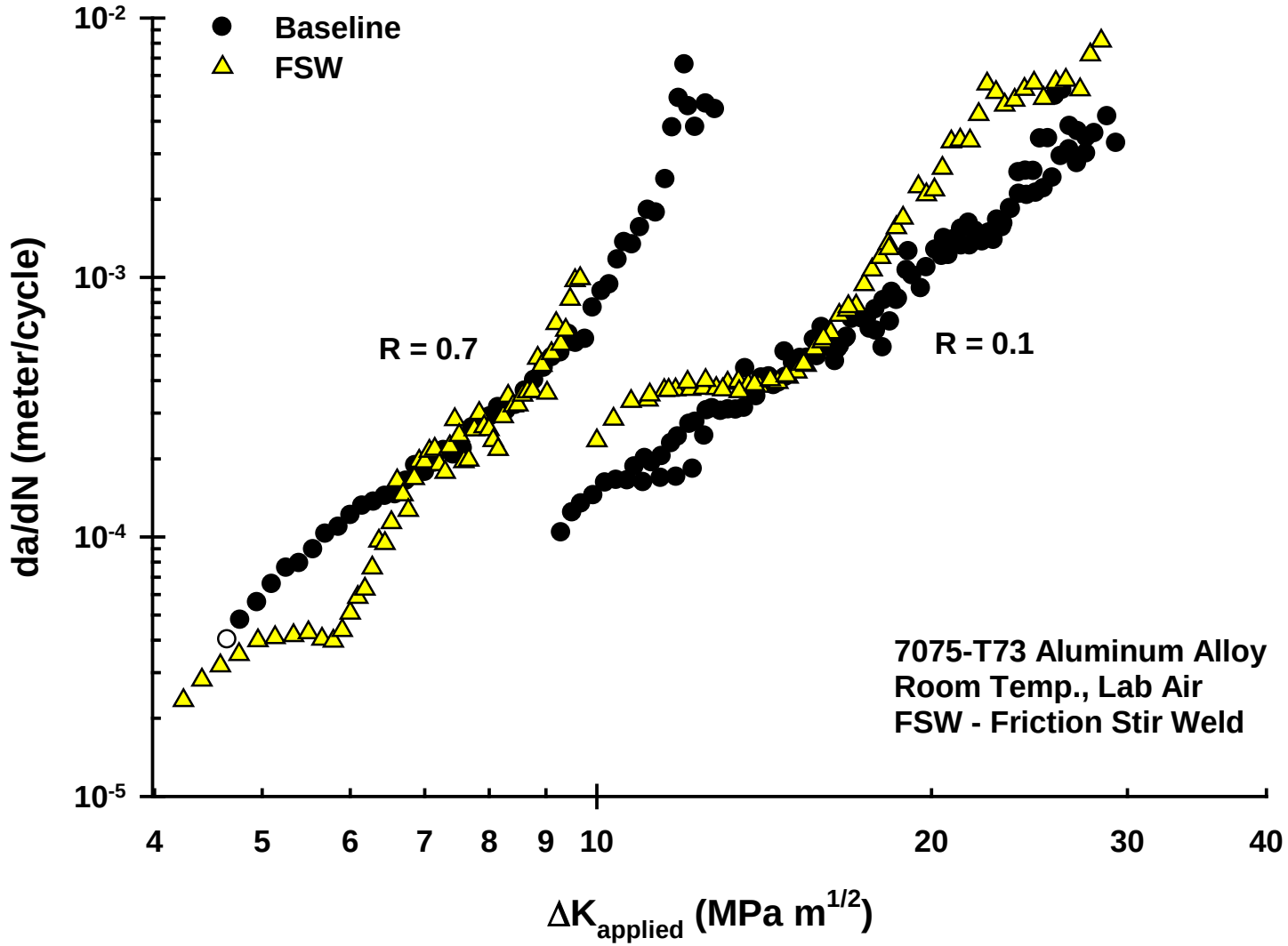


Residual Stress Measurements – 7075

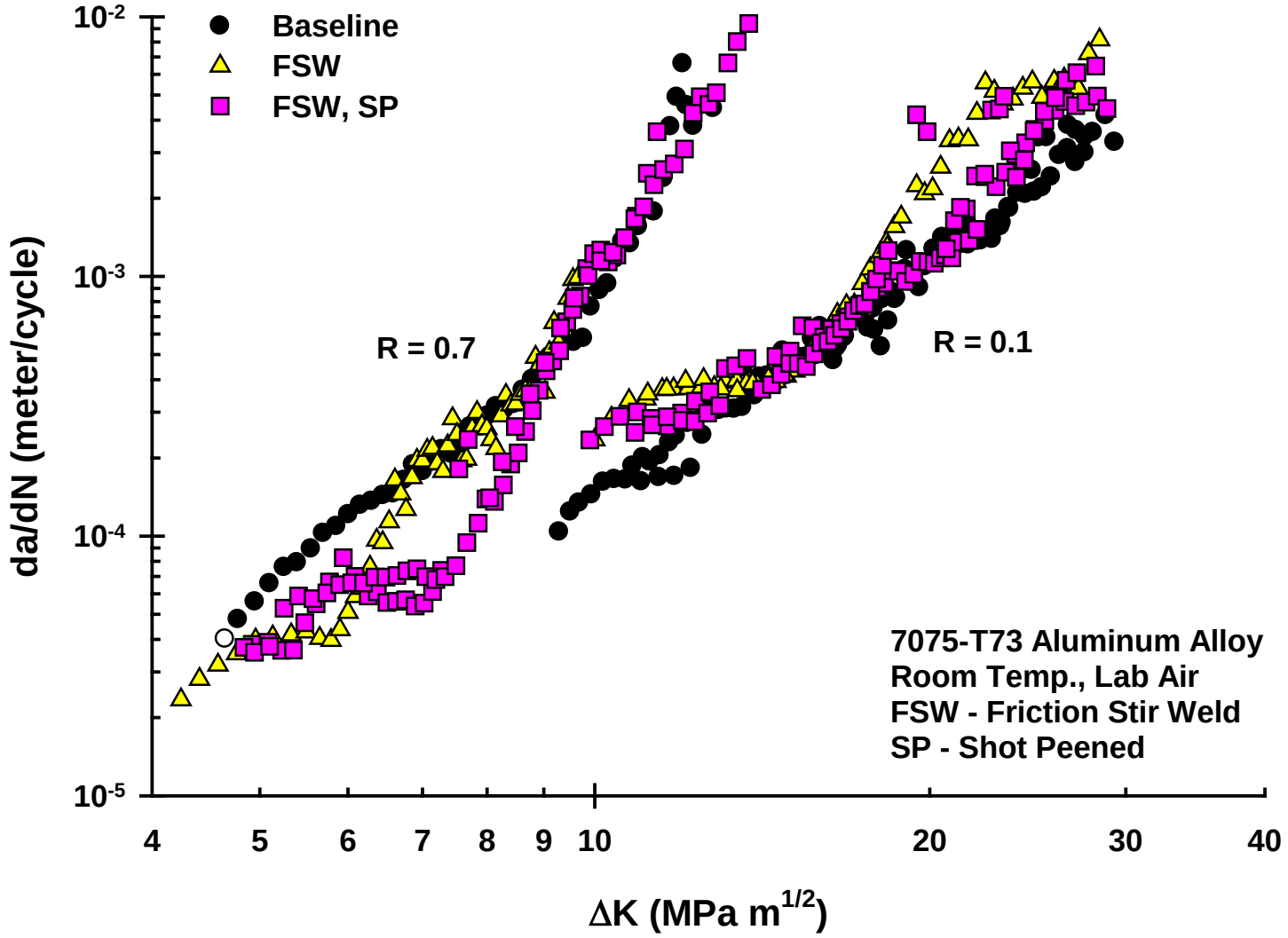


- Hardness testing performed for reference
- Residual stresses measured using X-ray diffraction and contour method (shown)
- Three dimensional stress field through the specimen thickness
- Stress intensity solution is two-dimensional
- Residual stresses **not** modeled in stress intensity calculations

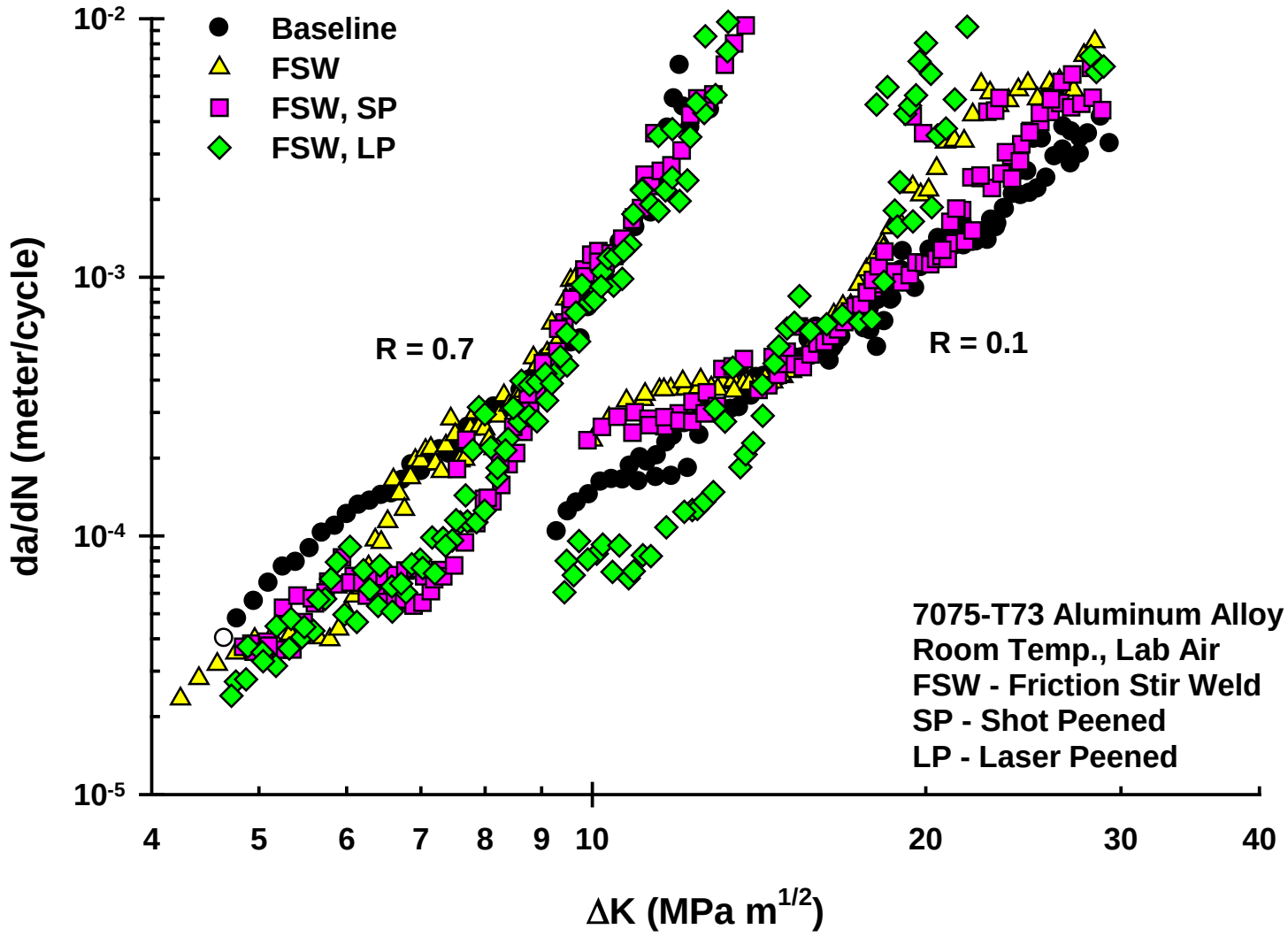
Fatigue Crack Growth Rate Post-Weld



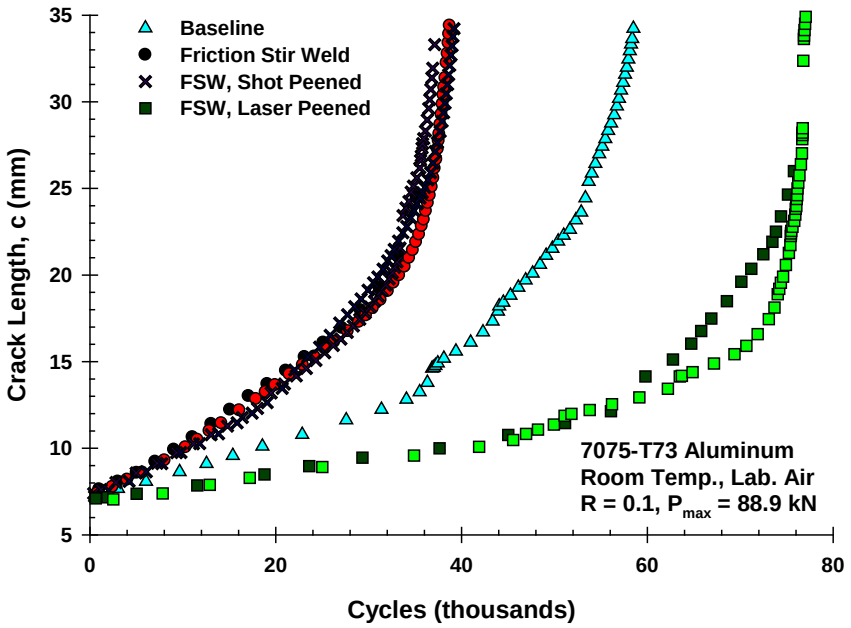
Fatigue Crack Growth Rate Post-Weld, Shot Peened



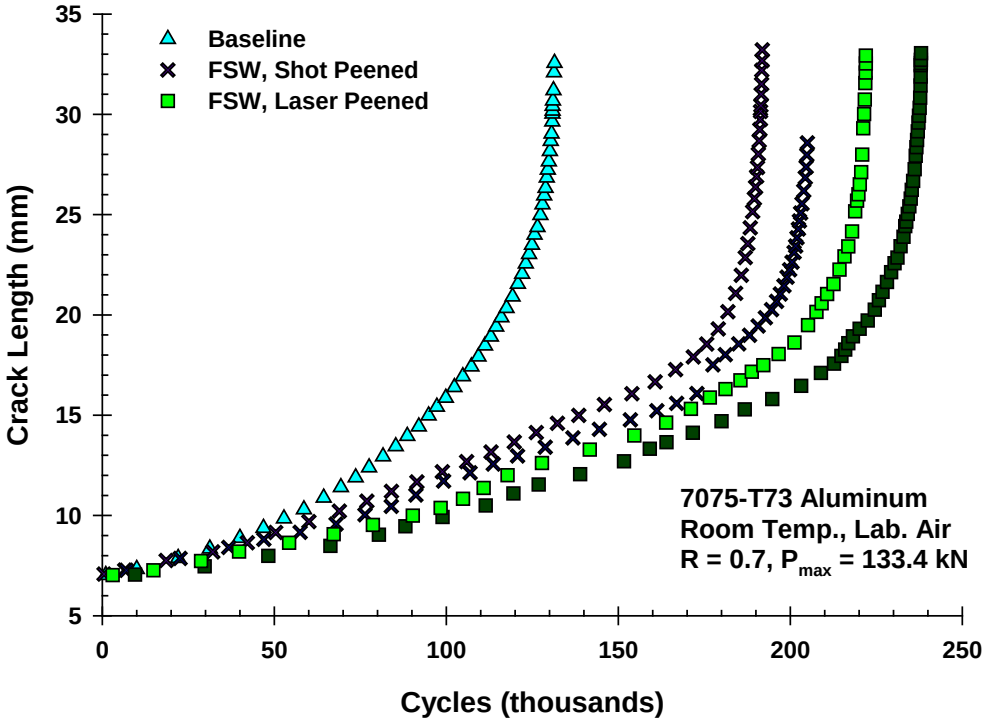
Fatigue Crack Growth Rate Post-Weld, Laser Peened



Crack Length versus Cycles

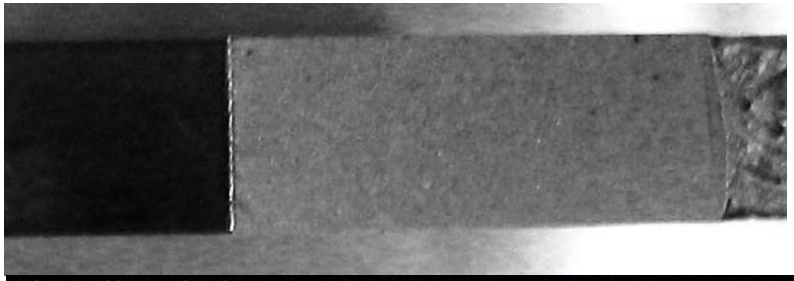


- Acceleration from welding
  - evident at R = 0.1
- Retardation from peening
  - unclear at R = 0.1 for shot



Fracture Surfaces – 7075 Aluminum

Base Material

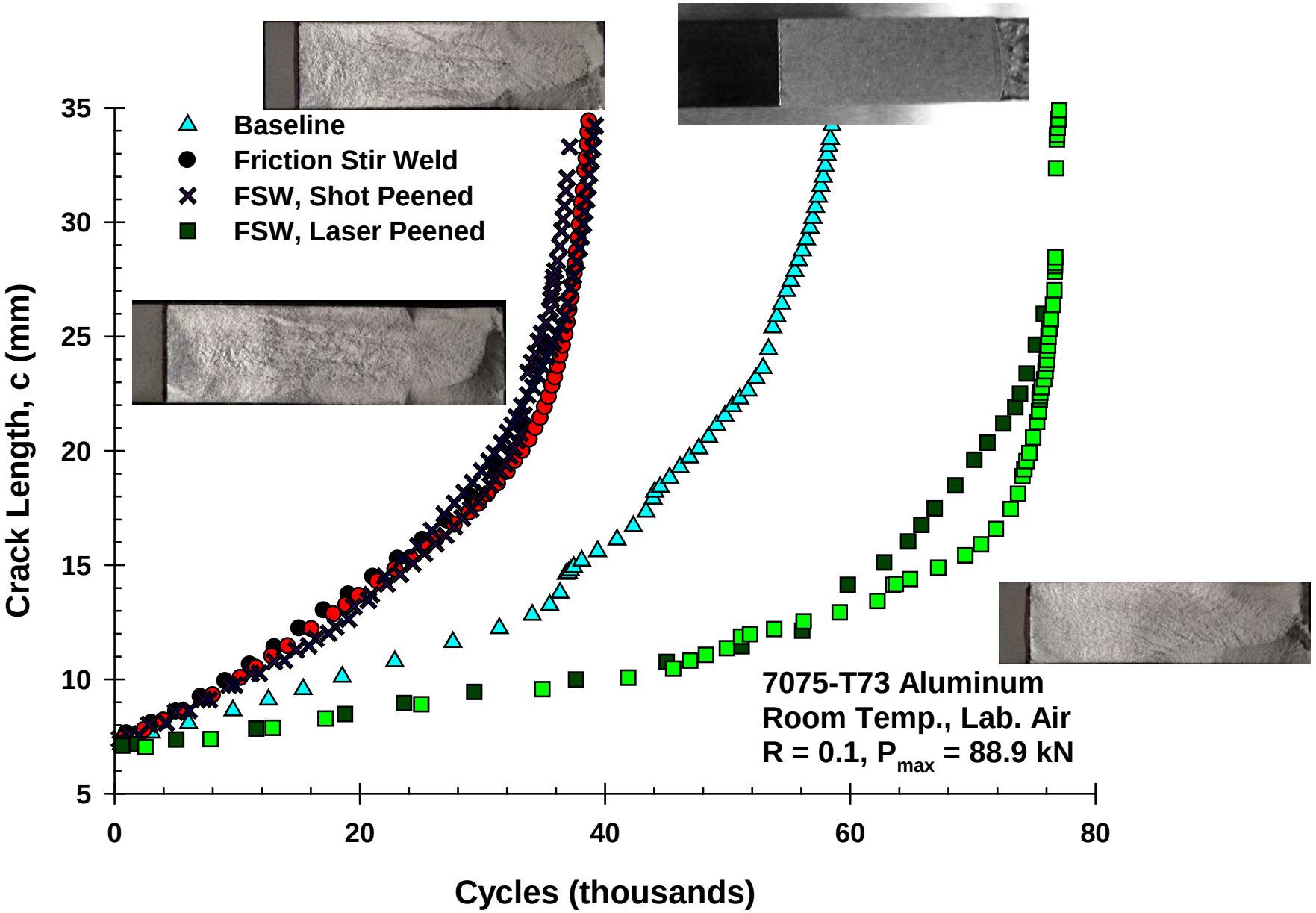


As-welded

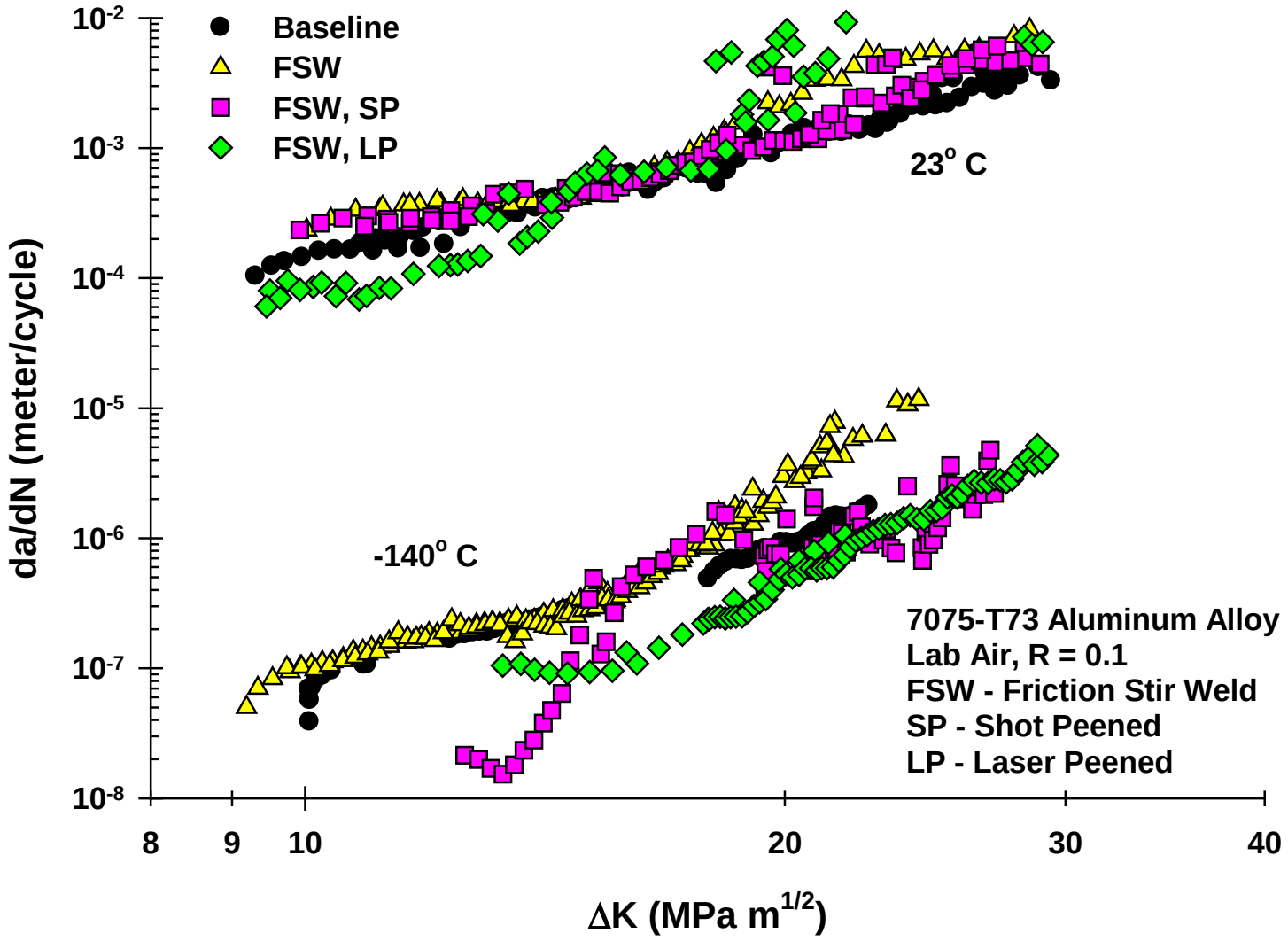
Welded,
Shot peened

Welded,
Laser peened

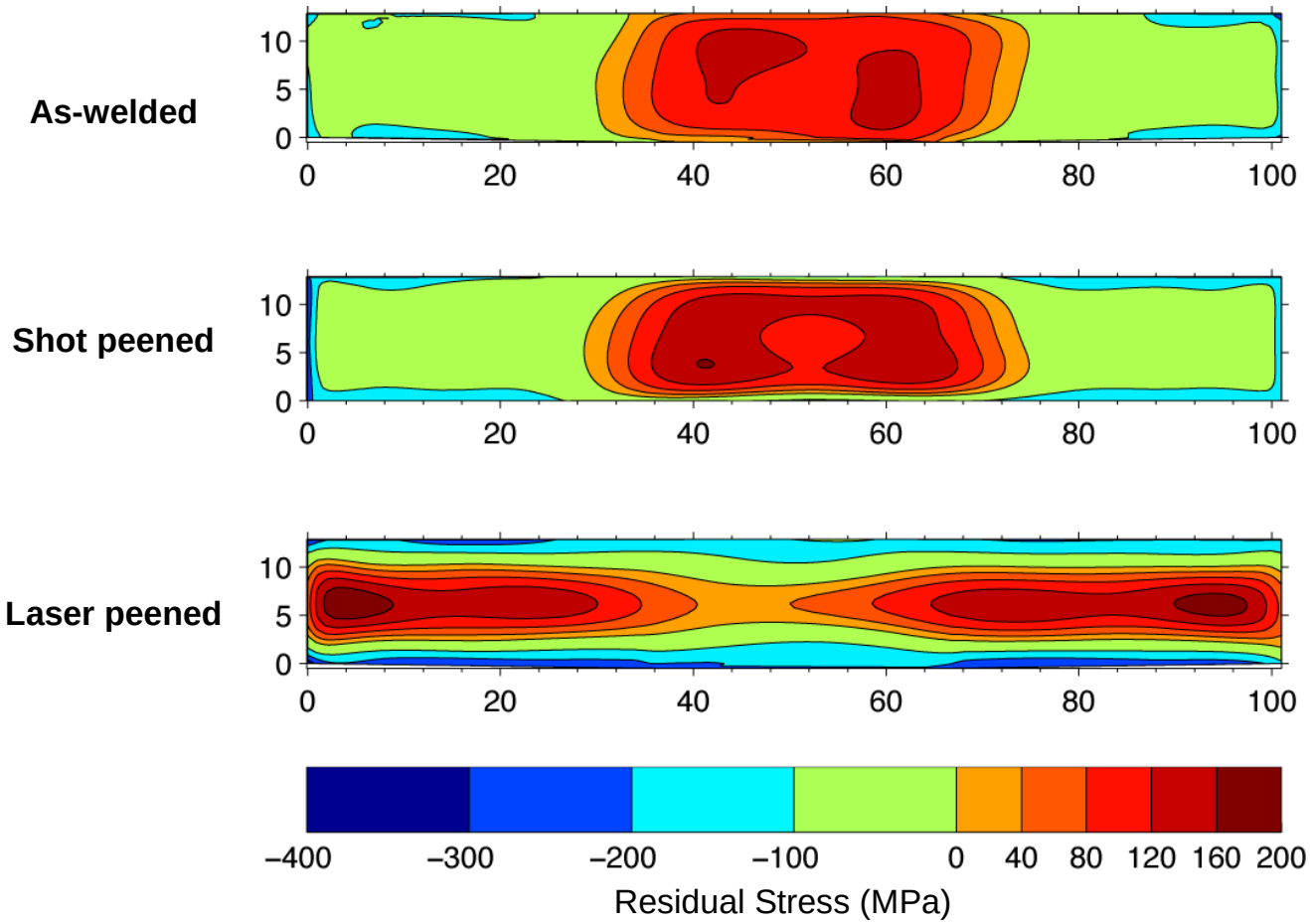
Fracture Surfaces – 7075 Aluminum



Effect of Temperature - 7075

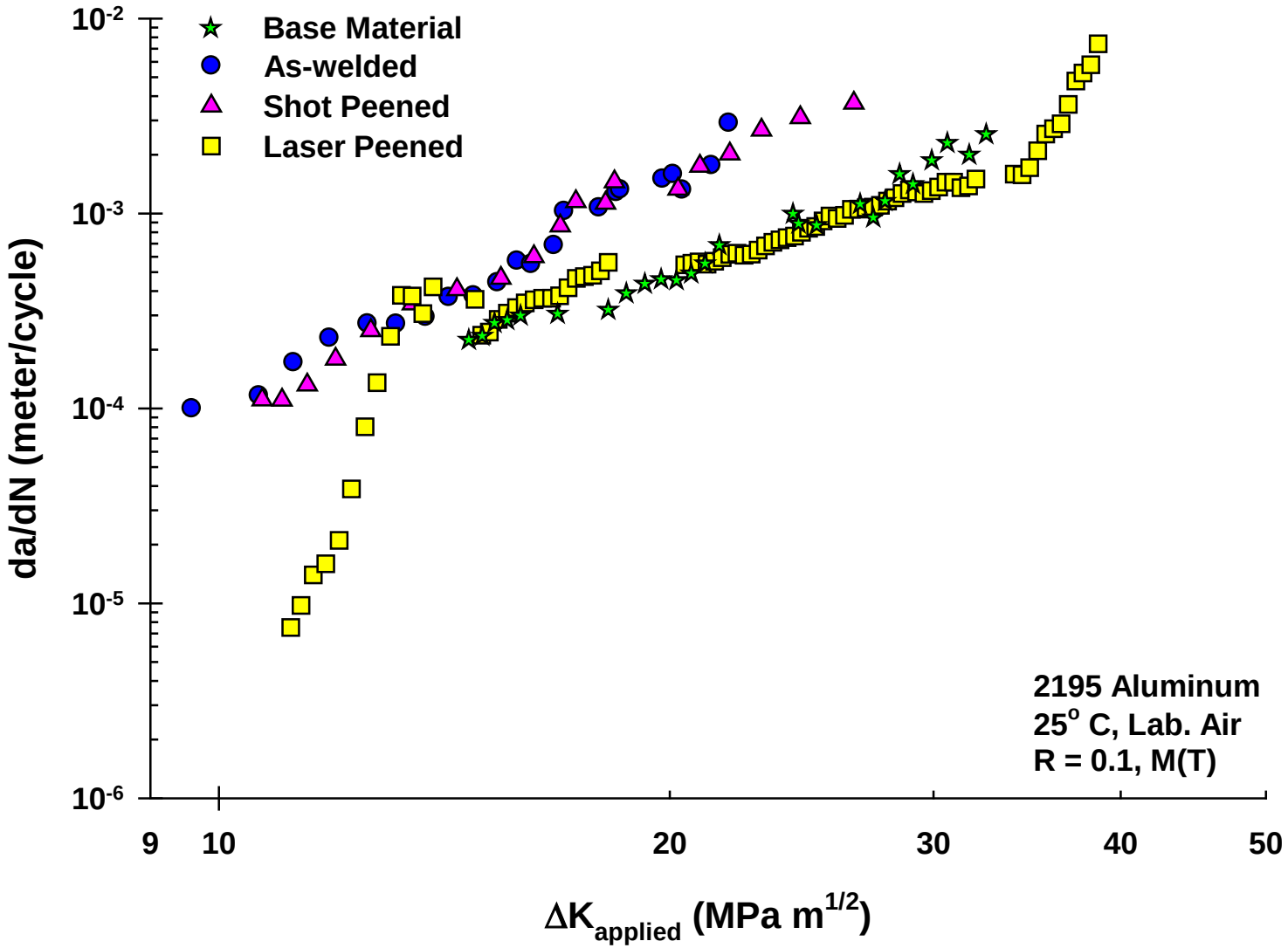


Residual Stress Measurements – 2195

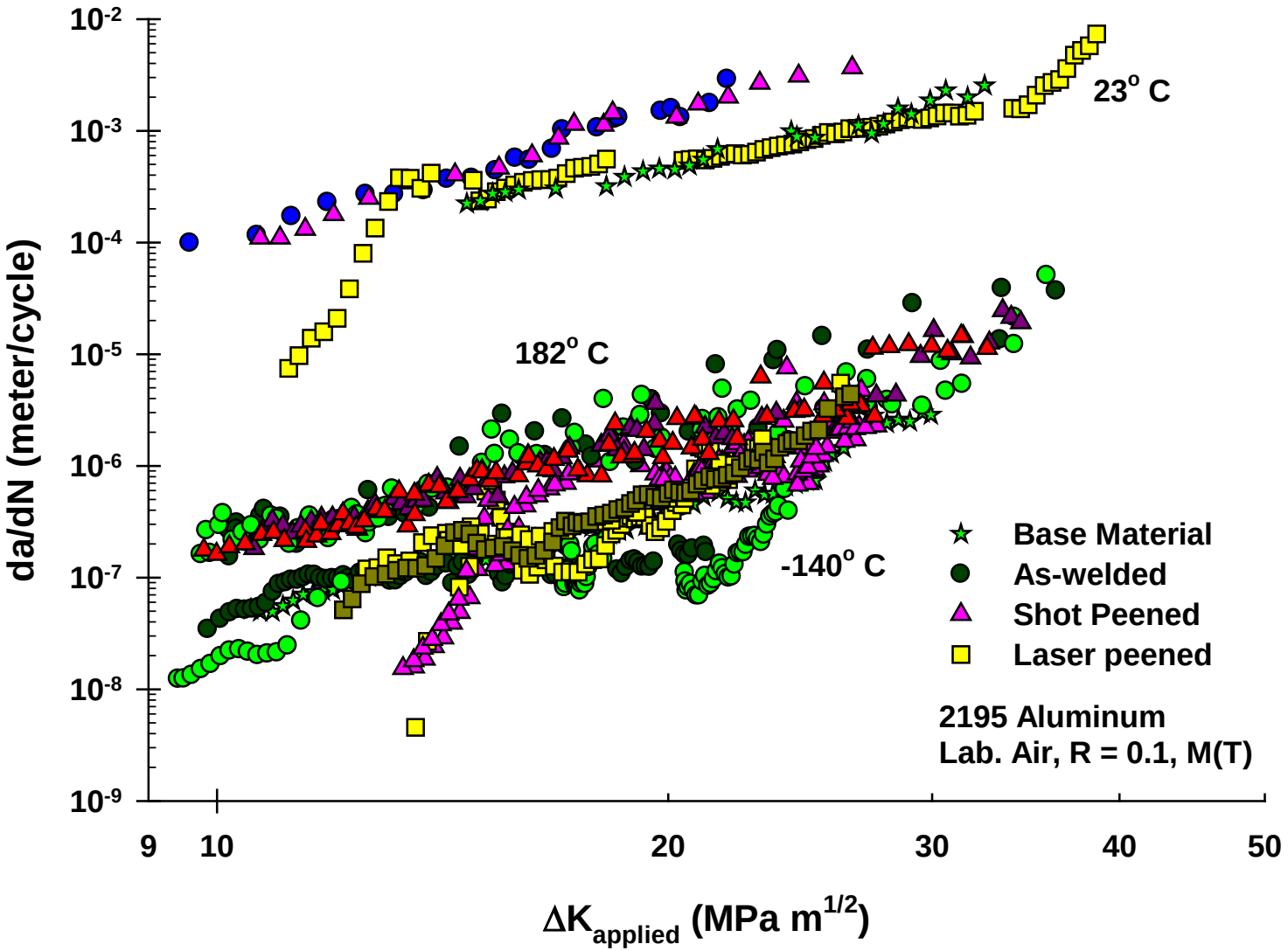


- Hardness testing performed for reference
- Residual stresses measured using X-ray diffraction and contour method (shown)
- Three dimensional stress field through the specimen thickness
- Stress intensity solution is two-dimensional
- Residual stresses **not** modeled in stress intensity calculations

Crack Growth Rate Data - 2195

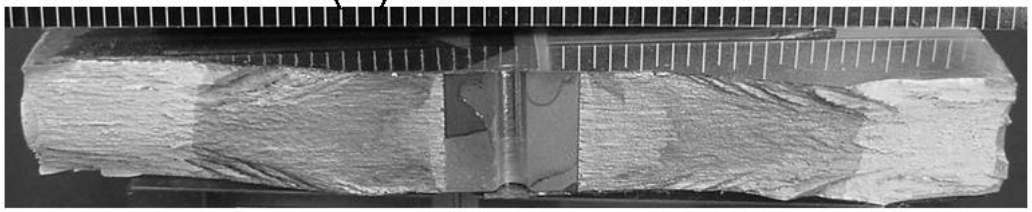


Effect of Temperature - 2195

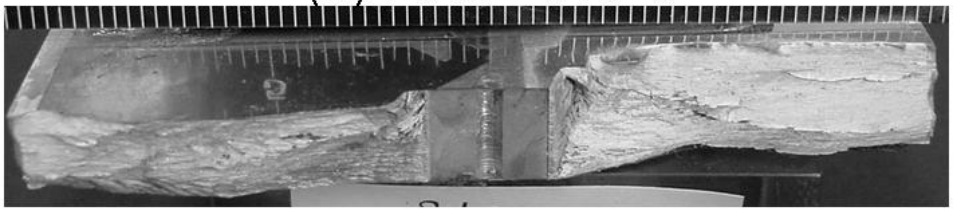


Fracture Surfaces - 2195

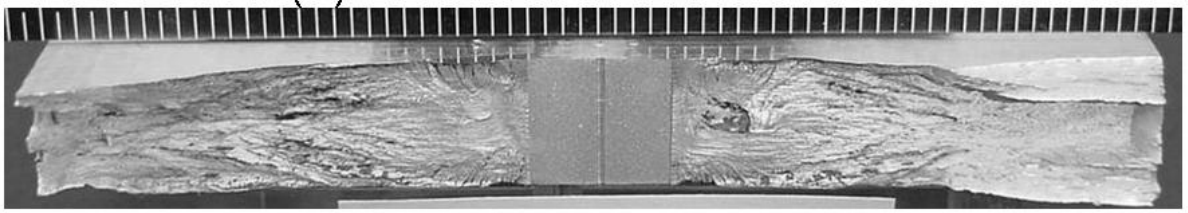
(a) Base -140°C



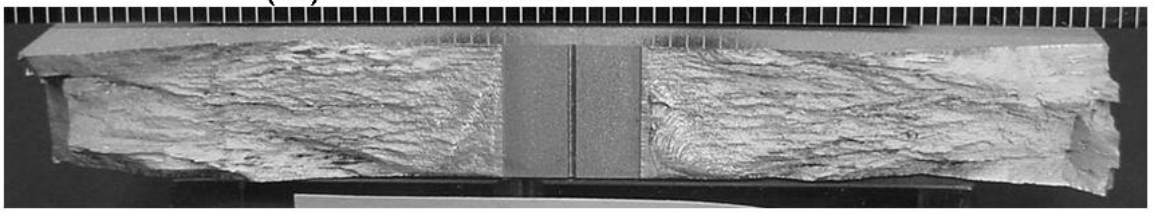
(b) FSW -140°C



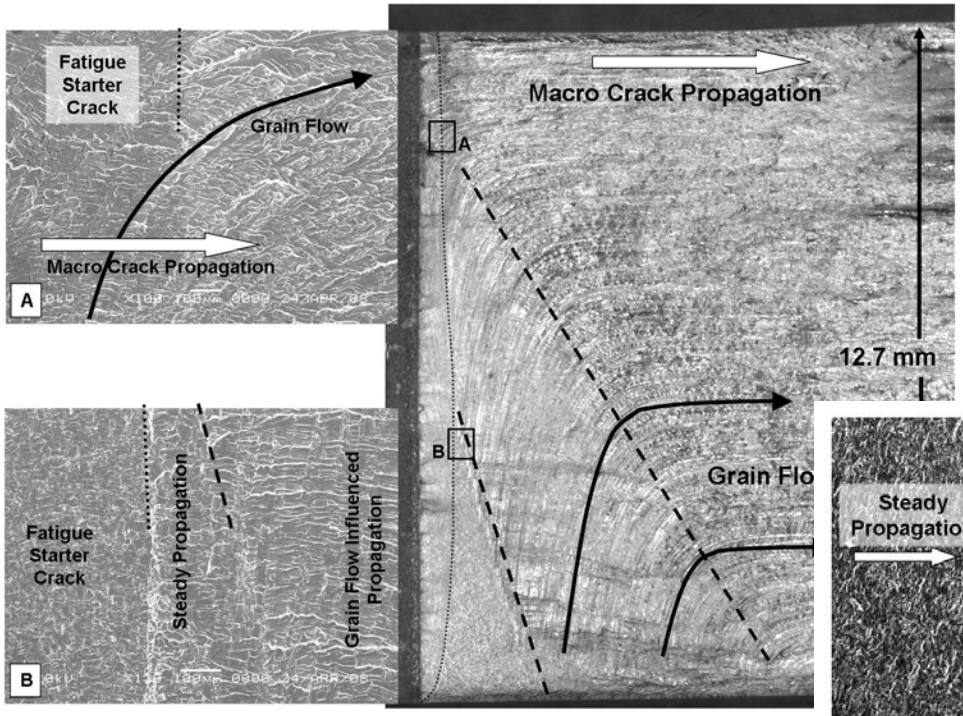
(c) Laser Peen FSW -140°C



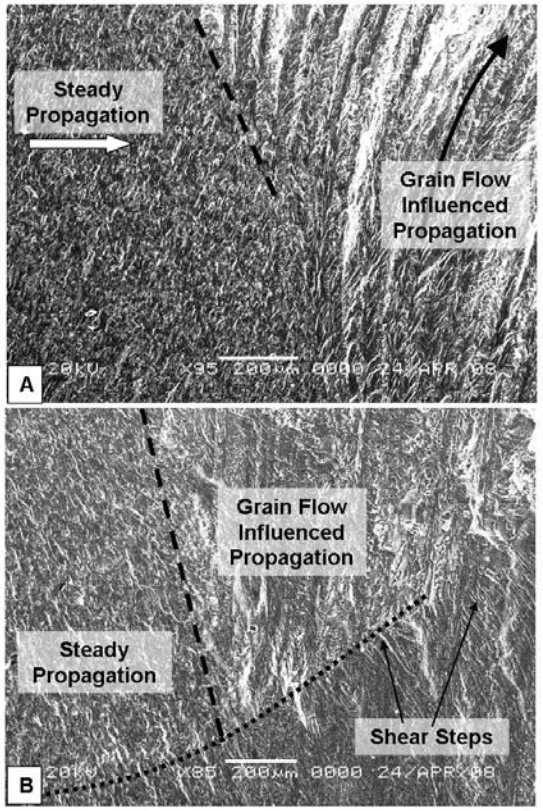
(d) Shot Peen FSW -140°C

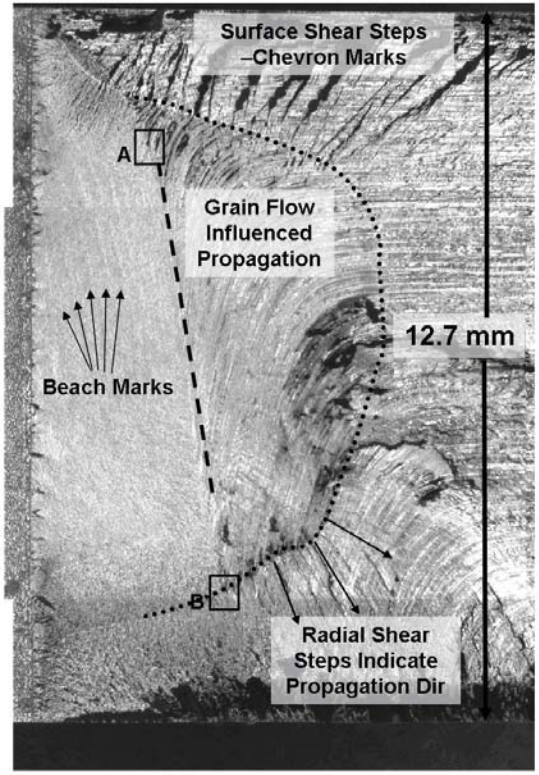


Fractography – Peening 2195

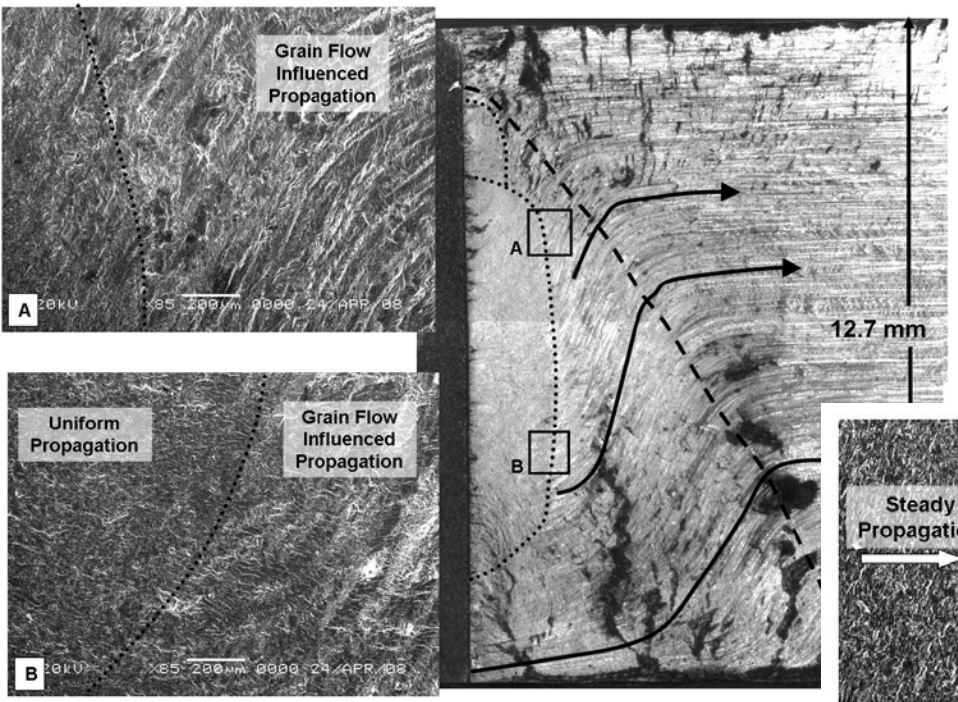


- Photographs from 182° C
- As-welded to the left, laser peened below

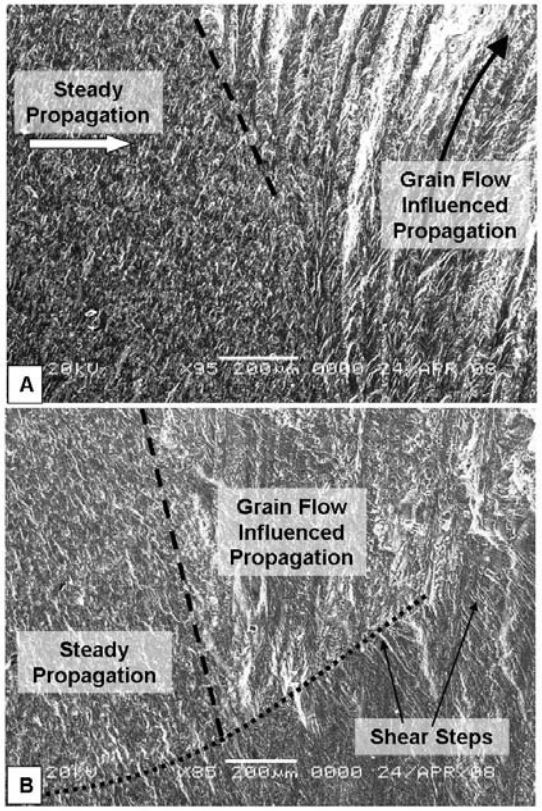


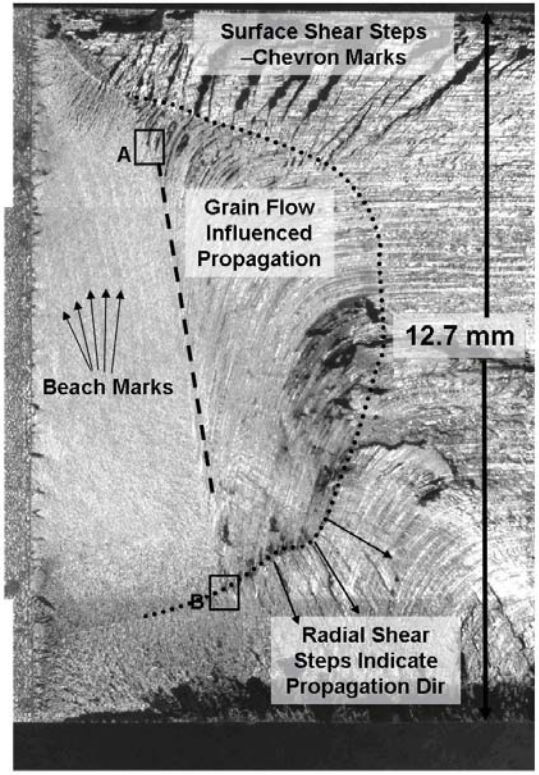


Fractography – Temperature 2195



- Photographs from laser peened
  Room temperature 23° C to the left, 182° C below





Observations

- **Friction stir welding induces residual stresses that accelerates fatigue crack growth in the weld nugget**
- **Shot peening over the weld had little effect on growth rate**
- **Laser peening over the weld retarded the growth rate**
  - Final crack growth rate was comparable to the base, un-welded material
  - Crack tunneling evident from residual compressive stresses
- **2195-T8 fracture surfaces were highly textured**
  - Texturing makes comparisons difficult as the material system is affecting the data as much as the processing
  - Material usage becoming more common in space applications requiring additional work to develop useful datasets for damage tolerance analyses